(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 564 263 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **93302507.4**

(51) Int. Cl.$^5$ : **G09G 3/36**

(22) Date of filing : **31.03.93**

(30) Priority : **01.04.92 JP 105285/92**

(43) Date of publication of application : **06.10.93 Bulletin 93/40**

(84) Designated Contracting States : **AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE**

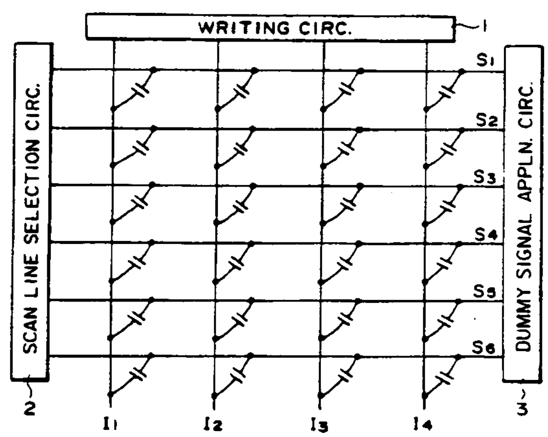
(71) Applicant : **CANON KABUSHIKI KAISHA
30-2, 3-chome, Shimomaruko, Ohta-ku
Tokyo (JP)**

(72) Inventor : **Okada, Shinjiro, c/o Canon K.K.
30-2, 3-chome Shimomaruko
Ohta-ku, Tokyo (JP)**
Inventor : **Inaba, Yutaka, c/o Canon K.K.
30-2, 3-chome Shimomaruko
Ohta-ku, Tokyo (JP)**
Inventor : **Kato, Takashi, c/o Canon K.K.
30-2, 3-chome Shimomaruko
Ohta-ku, Tokyo (JP)**
Inventor : **Katakura, Kazunori, c/o Canon K.K.
30-2, 3-chome Shimomaruko
Ohta-ku, Tokyo (JP)**

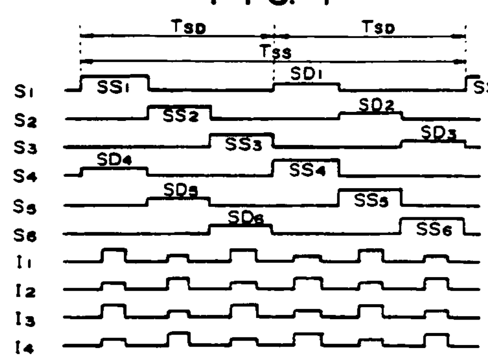
(74) Representative : **Beresford, Keith Denis Lewis et al
BERESFORD & Co. 2-5 Warwick Court High Holborn
London WC1R 5DJ (GB)**

(54) **Display apparatus.**

(57) A display apparatus is constituted by a display device including a plurality of scanning lines, a plurality of data lines intersecting the scanning lines, and a pixel formed at each intersection of the scanning lines and data lines and showing plural display states depending on signals applied to an associated scanning line and an associated data line. The display device is driven by applying a selection signal to the scanning lines and applying to the data lines data signals for causing prescribed display states at the pixels in association with the selection signal. Further, at least one scanning line in a nonselected state is supplied with a dummy signal for temporarily changing display states of pixels on the at least one scanning line, whereby flickering on the display device is suppressed. The display apparatus is also applicable to gradational display.




F I G. 4




F I G. 5

EP 0 564 263 A2

Another object of the present invention is to provide a display apparatus capable of displaying images with suppressed flickering without being affected by electrical response characteristic of a functional material, such as liquid crystal, constituting pixels.

A further object of the present invention is to provide a display apparatus provided with a flickering-suppressing function having a wide applicability through improvement of driving scheme.

A still further object of the present invention is to provide a display apparatus suitable for gradational (or gray-scale) display.

According to the present invention, there is provided a display apparatus, comprising:

a display device comprising a plurality of scanning lines, a plurality of data lines intersecting the scanning lines, and a pixel formed at each intersection of the scanning lines and data lines and showing plural display states depending on signals applied to an associated scanning line and an associated data line,

writing means for applying a selection signal to the scanning lines and applying to the data lines data signals for causing prescribed display states at the pixels in association with the selection signal, and

signal application means for applying to at least one scanning line in a nonselected state a dummy signal for temporarily changing display states of pixels on said at least one scanning line.

According to another aspect of the present invention, there is provided a display apparatus, comprising:

a display device comprising a plurality of scanning lines, a plurality of data lines intersecting the scanning line, and a pixel formed at each intersection of the scanning lines and the data lines,

a selection signal applying circuit for applying a selection signal to at least two adjacent scanning lines,

a data signal applying circuit for applying data signals comprising a gradation data to said plurality of data lines, and

a dummy signal applying circuit for applying a dummy signal to at least one of remaining scanning lines other than said at least two adjacent scanning lines receiving the selection signal,

wherein said selection signal includes a signal applied to one of said at least two adjacent scanning lines, which signal includes a signal component compensating for a display state given by a signal applied to the other of said at least two adjacent scanning lines.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a schematic sectional view of a display apparatus and Figure 1B is a plan view of an electrode plate used in the apparatus.

Figure 2 is a circuit diagram of a prior art display apparatus.

Figure 3 is a timing chart for illustrating a driving method for the prior art display apparatus.

Figure 4 is a circuit diagram of a display apparatus according to the invention.

Figure 5 is a timing chart (waveform diagram) for illustrating a driving scheme for a display apparatus according to the invention.

Figure 6 is a timing chart for illustrating another driving scheme for a display apparatus according to the invention.

Figure 7 is a graph for illustrating a relationship between a frame frequency of selection signal and flickering.

Figure 8 is a schematic sectional view of a liquid crystal device in a display apparatus according to Example 1 of the invention.

Figure 9 is a plan view showing an electrode arrangement in a display apparatus according to Example 1 of the invention.

Figure 10 is a graph showing a relationship between applied voltages and transmittances of a display apparatus according to Example 1.

Figure 11 is a schematic waveform diagram for illustrating a relationship among a scanning selection signal (a), a data signal (b) and a dummy signal (c) for a display apparatus according to Example 1.

Figures 12 and 13 are drive timing charts for a display apparatus according to Example 1.

Figure 14 is a drive system block diagram of a display apparatus according to Example 1.

Figure 15 is a block map for illustrating blocks allotted in a display panel according to Example 2 of the invention.

Figure 16 is a schematic waveform diagram for illustrating a relationship among a scanning selection signal (a), a data signal (b) and a dummy signal (c) for a display apparatus according to Example 1.

Figures 17 and 18 are drive timing charts for a display apparatus according to Example 1.

cordingly, when a scanning line constituting a picture is noted, if a drive circuit is so designed that a dummy signal is applied to the scanning line after the scanning line is once selected and the right quantity change caused by application of the dummy signal is not significantly different from the change caused by application of the selection signal, the pixels on the scanning line are apparently placed in a state similar to the case where the pixels are selected at a cycle of 25 msec. Thus, an identical picture state is formed 40 times a second so that flickering becomes unnoticeable.

The above-mentioned phenomenon is explained with reference to Figure 7, which is a graph obtained as a result of our study. Referring to Figure 7, the ordinate represents a frame frequency of selection signal for scanning one picture, and the abscissa represents the number (n) of active scanning lines. Herein, the active scanning line means a scanning line which is receiving a selection signal or a dummy signal. Accordingly, n = 1 in the case where one frame is written by selecting one scanning line at a time, and n = 2 in the case where writing is effected by selecting two scanning lines at a time. Further, n = 3 in the case where two lines are selected at a time and one line receives a dummy signal simultaneously. It is preferred that active scanning lines are disposed with equal spacings therebetween. This means that a particular scanning line noted has a constant time spacing ($T_{SD}$) from a time when the line is active to a time when the line is subsequently active. The circular marks connected by a solid line in Figure 7 represent minimum frame frequencies for obviating flickering at respective values of n. A frequency of 40 Hz is required at n = 1, while the frequency is reduced to about 30 Hz at n = 2 and about 19.2 Hz at n = 4. The minimum frequency ($f_{th}$) for obviating flickering and the number (n) of active scanning lines are summarized by the following relationship:

$$f_{th} = 40/n^{1/2} \quad (1).$$

The relationship (1) showing that $f_{th}$ is proportional to $1/n^{1/2}$ at a glance appears curious in view of the explanation so far made, which might rather suggest a relationship of $f_{th}$ being proportional to 1/n. It is considered that the difference between the actually measured data shown in Figure 7 and the previous explanation may be attributable to the following factors. A frequency $f_{eye}$ shown in Figure 7 represents a frequency below which human eyes can follow instantaneously a picture change even if the number (n) of active scanning lines is increased. Accordingly, below the frequency $f_{eye}$. The frequency $f_{eye}$ is tentatively shown as 12 Hz in Figure 7 but can be different for individuals, e.g., in a range of about 5 - 12 Hz. This may be reflected in commercialization. It is considered that $f_{eye}$ depends on the moving velocity of scanning lines ($V_{eye}$ = 1.8 m/sec in the case of Figure 7) rather than on the frame frequency. Anyway, it is considered that the reason why $f_{th}$ does not change linearly with an increase in n is attributable to a phenomenon that the minimum frequency for obviating flickering gradually approaches not to zero but to $f_{eye}$ because of the presence of $f_{eye}$ and human eyes characteristics giving $f_{eye}$. In Figure 7, triangular marks connected by a dashed line represent frequencies causing an acceptable degree of flickering. As described above, even in case where a picture display drive cannot be effected at 40 Hz because of a slow one line selection time, it is possible to realize a flicker-free picture by application of a dummy signal to increase the number of active scanning lines on one picture.

A pixel used in the present invention may preferably be one comprising a liquid crystal sandwiched between a pair of electrodes or one obtained by further adding thereto an active element, such as a MIM element.

The liquid crystal may preferably be a nematic liquid crystal or a ferroelectric liquid crystal (FLC).

A ferroelectric liquid crystal shows a quick response speed and have many advantages, such as a wide viewing angle, when used in a display apparatus, so that it is particularly suitably used in the present invention.

Display apparatus using a ferroelectric liquid crystal have been described in detail, e.g., in U.S. Patent No. 4,367,924 issued to N.A. Clark and Lagerwall, U.S. Patent No. 4,655,561 issued to Kanbe, et al., Japanese Laid-Open Patent Application (JP-A) 61-94023, and N.A. Clark, et al. MCLC, 1983, Vol. 94, pp. 213 - 214.

Such a display apparatus using a ferroelectric liquid crystal may for example have a structure including a pair of glass plates each having transparent electrodes thereon and provided with an aligning treatment and disposed opposite to each other with a gap on the order of 1 - 3 μm therebetween to form a cell, and a ferroelectric liquid crystal injected into the cell. The display apparatus using a ferroelectric liquid crystal has advantageous features that the switching can be effected by utilizing a force of coupling of a spontaneous polarization of the ferroelectric liquid crystal and an external electric field, and the switching can be effected depending on the polarity of the external electric field because the long axis of an FLC molecule corresponds to the polarization direction of the spontaneous polarization in a one-to-one correspondence. The ferroelectric liquid crystal may generally comprise a chiral smectic liquid crystal (SmC*, SmH*) and is therefore shows an alignment that its molecular long axis is helical. However, if the ferroelectric liquid crystal is disposed in a cell having a cell gap on the order of 1 - 3 μm as described above, the helix of the liquid crystal molecular long axis is unwound.

The display apparatus according to the present invention may be one displaying binary image data, such as white and black, or one displaying multi-value image data such as a color image and/or a gradational (gray-scale) image.

mfd. by Hitachi Kasei K.K.) by spin coating, followed by baking to form an about 300 Å-thick polyimide alignment film 24a. Separately, an opposite substrate (electrode plate) was formed by forming on a flat surface of a glass substrate 21 ITO stripe electrodes (data lines) 22b and thereon an alignment film 24b similar to the film 24a. Then, the alignment films 24a and 24b were respectively rubbed in one direction.

A pair of the rubbed substrates were superposed so that their rubbing directions were almost parallel but the rubbing direction of the lower substrate deviated by about 6 degrees in a right-screw direction with respect to the rubbing direction of the upper substrate to form a blank cell. The cell thickness (liquid crystal layer thickness) was controlled so that the smallest thickness was about 1.0 μm and the largest thickness was about 1.4 μm. The stripe electrode 22a was designed to have a width of 300 μm and the stripe electrode 22b was designed to have a width of 200 μm so as to provide a rectangular pixel size of 300 μm x 200 μm. The resultant panel was as shown in Figure 9 including scanning electrodes $S_1$ - $S_{1024}$ as Y-direction electrodes and data electrodes $I_1$ - $I_{1000}$ as X-direction electrodes. The used ferroelectric liquid crystal 26 showed a phase transition series and physical properties as shown in Table 1 below.

Table 1

$$\text{Iso.}\ \underset{81.8^{\circ}C}{\overset{82.3^{\circ}C}{\rightleftarrows}}\ \text{Ch.}\ \underset{77.3^{\circ}C}{\overset{76.6^{\circ}C}{\rightleftarrows}}\ \text{SmA}\ \overset{54.8^{\circ}C}{\longleftrightarrow}\ \text{SmC}^{*}\ \underset{-2.5^{\circ}C}{\overset{-20.9^{\circ}C}{\rightleftarrows}}\ \text{Cryst.}$$

$$Ps = 5.8\ nC/cm^2 \text{ at } 30\ ^{\circ}C$$

$$\text{Tilt angle} = 14.3 \text{ degrees at } 30\ ^{\circ}C$$

$$\Delta\varepsilon \doteqdot 0 \text{ at } 30\ ^{\circ}C$$

The ferroelectric liquid crystal when used in a panel having a cell thickness of 1 μm showed a pulse width-voltage characteristic (a relationship between threshold switching pulse width and voltage) as shown in Figure 10, thus showing, e.g., a threshold voltage intensity of 11.5 volt/μm at a pulse width of 80 μsec and 25 °C. Accordingly, the liquid crystal panel (liquid crystal device) shown in Figure 8 showed threshold voltages ranging from 11.5 volt - 16.1 volt for an 80 μsec pulse at 25 °C.

Figure 11 shows a set of driving voltage waveforms. Referring to Figure 11, at (a) is shown a scanning signal waveform, at (b) is shown a data signal waveform, and at (c) is shown a dummy signal waveform as an improvement given by the present invention. The scanning signal waveform shown at (a) includes a reset pulse $P_1$, a selection pulse $P_2$ for writing on a scanning line concerned, a selection pulse $P_3$ for compensating for a threshold change of the ferroelectric liquid crystal as caused by a temperature change for an adjacent scanning line, and an auxiliary pulse $P_4$. The data signal waveform shown at (b) includes a selection pulse $Q_1$ carrying gradation data and auxiliary pulses $Q_2$ and $Q_3$ counterbalancing the DC component of $\theta_1$. In Figure 11, $1H_B$ denotes a period of applying the data signal waveform for the scanning line concerned, and $1H_A$ denotes a period of applying the data signal waveform for the adjacent scanning line. Further, $\Delta T$ denotes a period in which the selection pulses $P_2$ and $Q_1$ and the selection pulse $P_3$ and $Q_1'$ are respectively synchronized. The dummy signal waveform shown at (c) is constituted as an alternating current waveform free from remaining DC component and designed to have a voltage which does not change the data in a pixel even if a combination thereof with a data signal is applied to the liquid crystal layer. The dummy signal is applied so as to apply a voltage insufficient to cause inversion of liquid crystal molecules but perturb the liquid crystal molecules to make the flickering unnoticeable.

Next, the time serial setting and operation of the driving waveforms are described with reference to Figures 12 and 13. Referring to Figures 12 and 13, at $S_1$ - $S_8$ and $S_{250}$ - $S_{257}$ are shown selection signals and dummy signals, respectively, applied to, e.g., 16 scanning lines $S_1$ - $S_8$ and $S_{250}$ - $S_{257}$ among 1024 scanning lines $S_1$ - $S_{1024}$ within an identical period.

For example, when a selection signal is applied to a scanning line $S_1$, a dummy signal is simultaneously applied to four scanning lines $S_{251}$, $S_{501}$, $S_{751}$ and $S_{1001}$ actually in this embodiment. Then, when a selection signal is applied to a scanning line $S_2$, a dummy signal is applied to four scanning lines $S_{252}$, $S_{502}$, $S_{752}$ and $S_{1002}$. Further, the selection signal is line-sequentially applied to the subsequent scanning lines $S_3$ - $S_{1024}$, while the dummy signal is simultaneously applied to three or four scanning lines spaced apart from each other by 250 lines based on the selected scanning line. As a result, each scanning line on the panel is supplied a se-

within the voltage application period.

In this embodiment, an interlaced scanning scheme may be adopted in combination so as to effect a good image display even in the case of sequentially selecting the scanning lines with such a prolonged interval.

More specifically, in this embodiment, the scanning lines of a matrix panel as shown in Figure 9 are divided into two blocks as shown in Figure 15, and an interlaced scanning is performed. Referring to Figure 15, a block A includes scanning lines $S_1$ - $S_{512}$, and a block B includes scanning lines $S_{513}$ - $S_{1024}$. The scanning lines are selected in the order of $S_1$, $S_{513}$, $S_2$, $S_{514}$, $S_3$, $S_{515}$, ..., i.e., alternate selection from the respective blocks and line-sequential selection within each block. In this instance, a dummy signal is simultaneously applied to four scanning lines with a spacing of 250 lines each in the respective blocks. As a result, a good gradational display could be realized with remarkably suppressed flicker compared with the case where the dummy signal was not applied. This example was the same as Example 1 except for the difference in scanning scheme.

Example 3

In this embodiment, such a dummy signal is applied to the scanning lines that the change in transmitted light quantity through pixels on a scanning line at the time of selection by application of a selection signal is substantially equal to the change in transmitted light quantity through pixels on a scanning line at the time of dummy signal application.

In the method described so far, a certain degree of flicker-removing effect is attained, if the transmitted light quantity change (I) at the time of selection of a scanning line and the transmitted light quantity change (II) at the time of dummy signal application satisfy a relationship of (I)/(II) $\leqq$ 2.0. In order to obtain a better result, it is desired that (I) and (II) are almost equal. If the transmitted light quantity change by application of a dummy signal is too large, one time of dummy signal application may not damage the image but a repetitive application of the dummy signal over several frames can gradually damage the image data. In order to avoid the problem, it is desired to suppress the transmitted light quantity change through the scanning line. For this reason, in this embodiment, a dummy signal is applied to consecutive two scanning lines and the voltage value of the dummy signal is lowered. A set of driving voltage waveforms used in this embodiment are shown in Figure 16, and timing charts for application of the waveforms are shown in Figures 17 and 18.

As shown at S251 - S258, the dummy signal is applied simultaneously to two scanning lines and also applied to the other scanning lines line-sequentially. For example, scanning line $S_{251}$ and $S_{252}$ are simultaneously supplied with a voltage $+V_S$. In a particular example, the pulse width and voltage value of the respective pulses shown in Figure 16 were set as follows:

$$dt_1 = 70\ \mu sec,\ dt_2 = 50\ \mu sec,$$
$$dt_3 = 31\ \mu sec,\ dt_4 = 19\ \mu sec,$$
$$V_0 = 25\ volts,\ V_1 = 18\ volts,$$
$$V_2 = 18\ volts,\ V_3 = 4.5\ volts.$$

The voltage value Vi for displaying a gradation state of x % was determined based on the above-mentioned formula (2) or (3).

By suppressing the degree of perturbation of liquid crystal molecules caused by application of a dummy signal for one scanning line, it was possible to realize a ferroelectric liquid crystal display apparatus with a further improved stability. The liquid crystal device used in Example 3 was the same as in Example 1, and the other conditions were also the same as in Example 1 except for the above-described drive conditions.

As described hereinabove, by applying a selection signal to a scanning line and simultaneously applying a dummy signal to another scanning line according to the present invention, it has become possible to realize good binary display and gradational display free from or with less flickering even if one-line scanning speed is slow.

**Claims**

1. A display apparatus, comprising:

a display device comprising a plurality of scanning lines, a plurality of data lines intersecting the scanning lines, and a pixel formed at each intersection of the scanning lines and data lines and showing plural display states depending on signals applied to an associated scanning line and an associated data line,

writing means for applying a selection signal to the scanning lines and applying to the data lines data signals for causing prescribed display states at the pixels in association with the selection signal, and

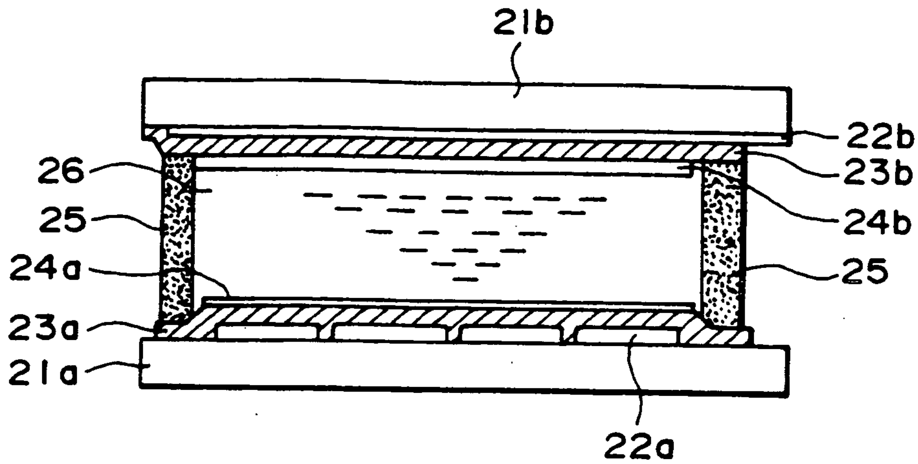



FIG. 1A

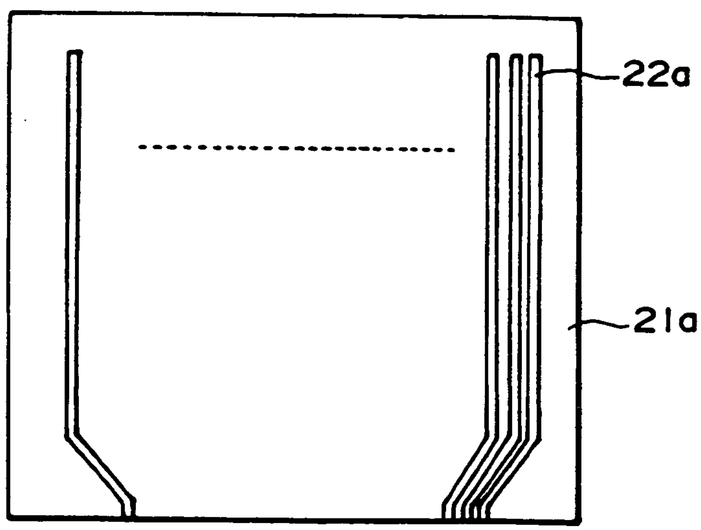



FIG. 1B

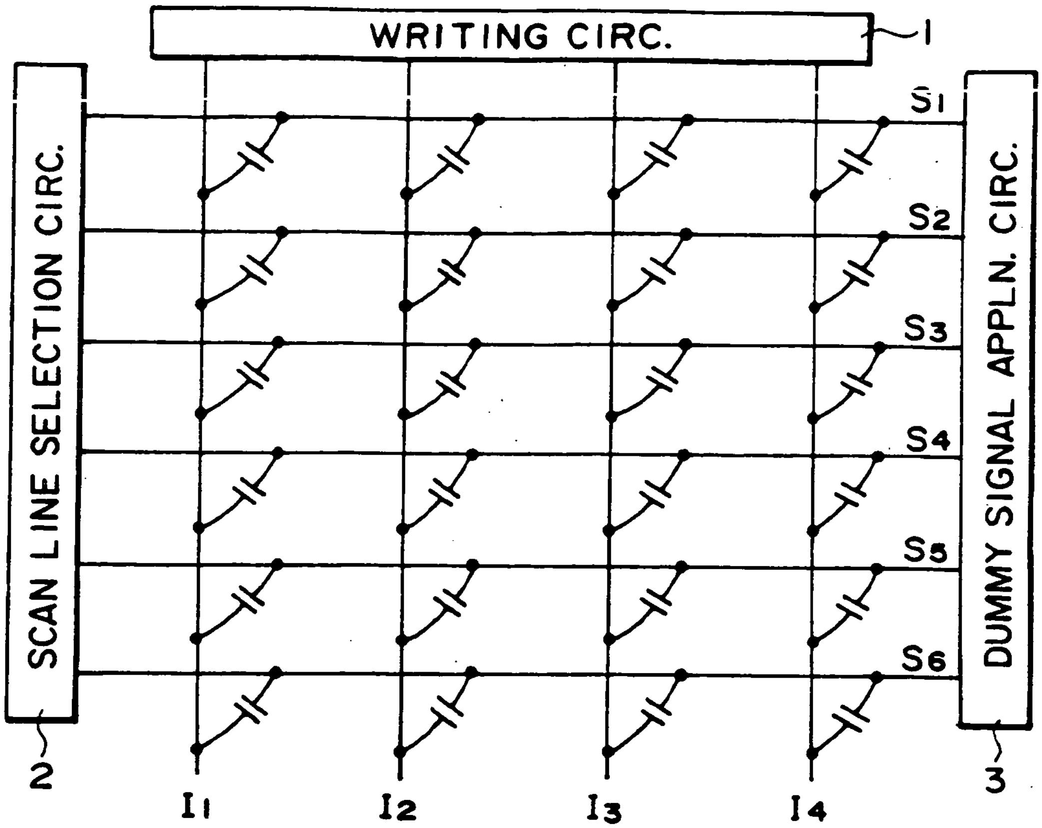

WRITING CIRC.
1
SCAN LINE SELECTION CIRC.
DUMMY SIGNAL APPLN. CIRC.
S1
S2
S3
S4
S5
S6
2
3
I1
I2
I3
I4

FIG. 4

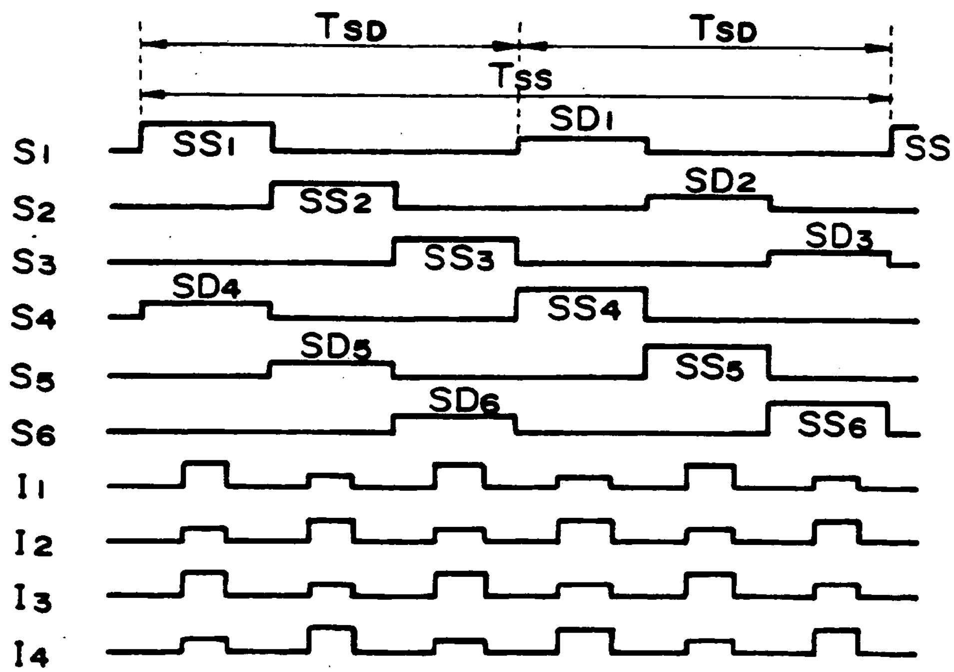

TSD
TSD
TSS
S1
SS1
SD1
SS1
S2
SS2
SD2
S3
SS3
SD3
S4
SD4
SS4
S5
SD5
SS5
S6
SD6
SS6
I1
I2
I3
I4

FIG. 5

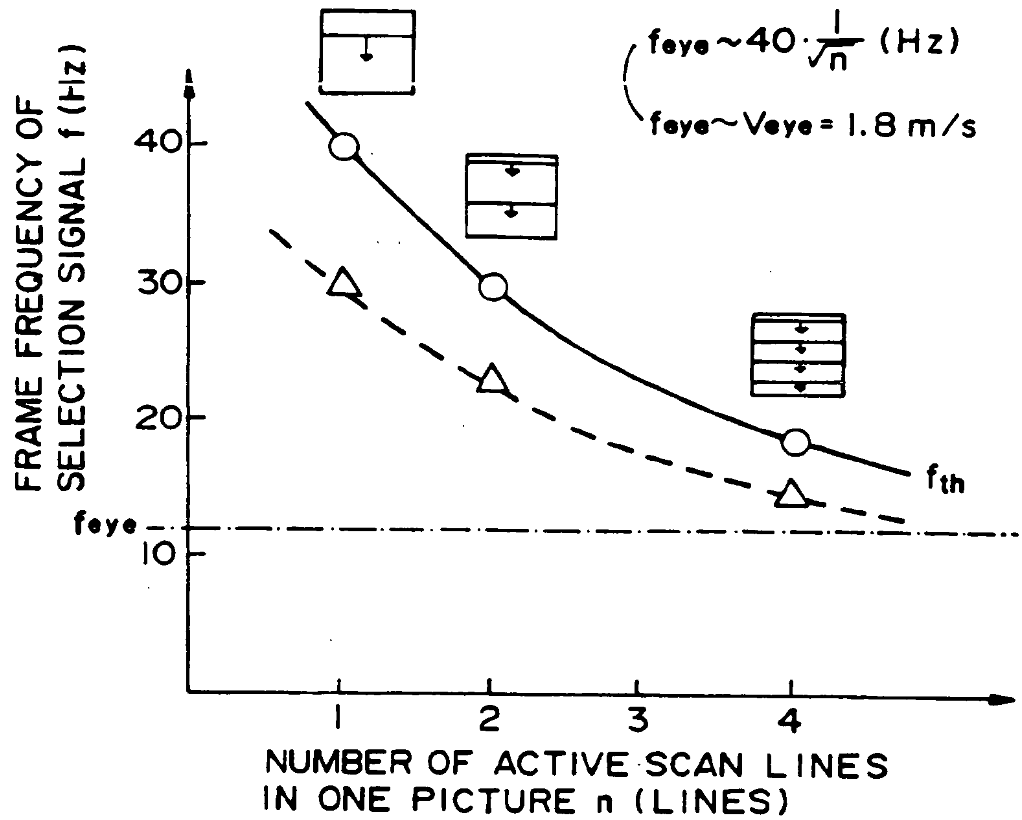

FRAME FREQUENCY OF SELECTION SIGNAL f (Hz)
40
30
20
10
feye
$f_{eye} \sim 40 \cdot \frac{1}{\sqrt{n}}$ (Hz)
$f_{eye} \sim V_{eye} = 1.8$ m/s
$f_{th}$
1
2
3
4
NUMBER OF ACTIVE SCAN LINES IN ONE PICTURE n (LINES)

FIG. 7

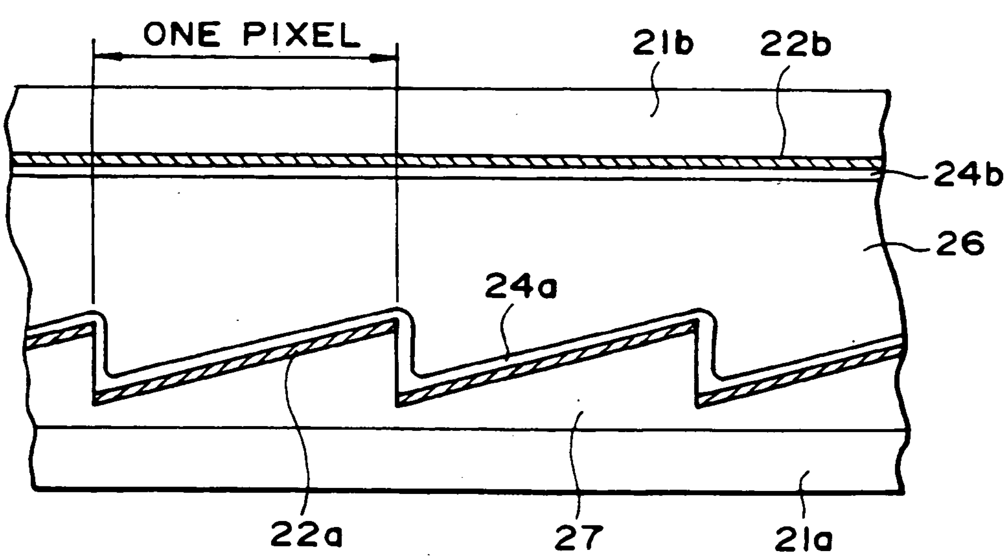
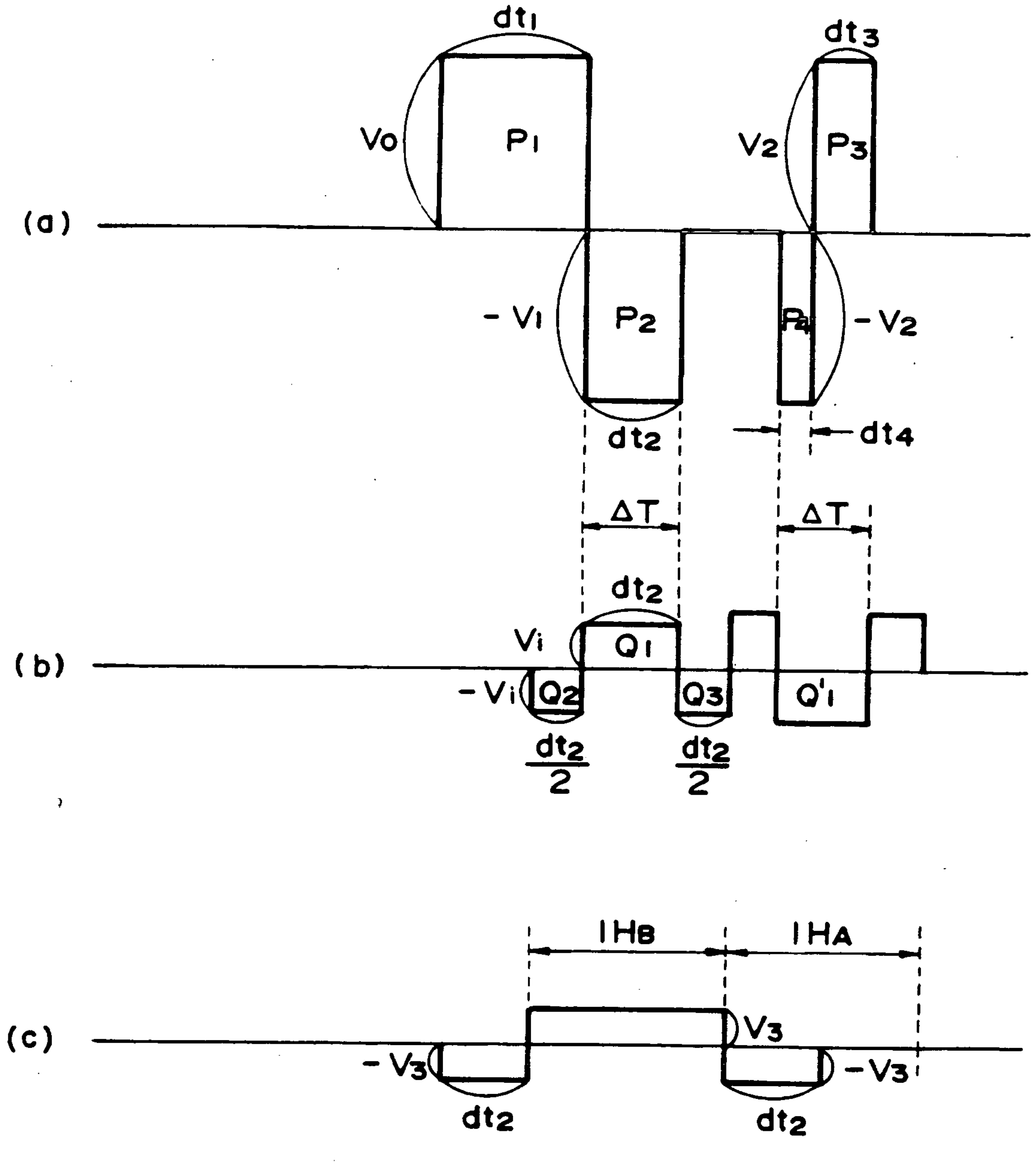

ONE PIXEL
21b
22b
24b
26
24a
22a
27
21a

FIG. 8


(a)
dt1
Vo
P1
-V1
P2
dt2
dt3
V2
P3
P4
-V2
dt4
ΔT
ΔT
(b)
dt2
Vi
Q1
-Vi
Q2
Q3
Q'1
dt2/2
dt2/2
(c)
1HB
1HA
V3
-V3
-V3
dt2
dt2

F I G. 11

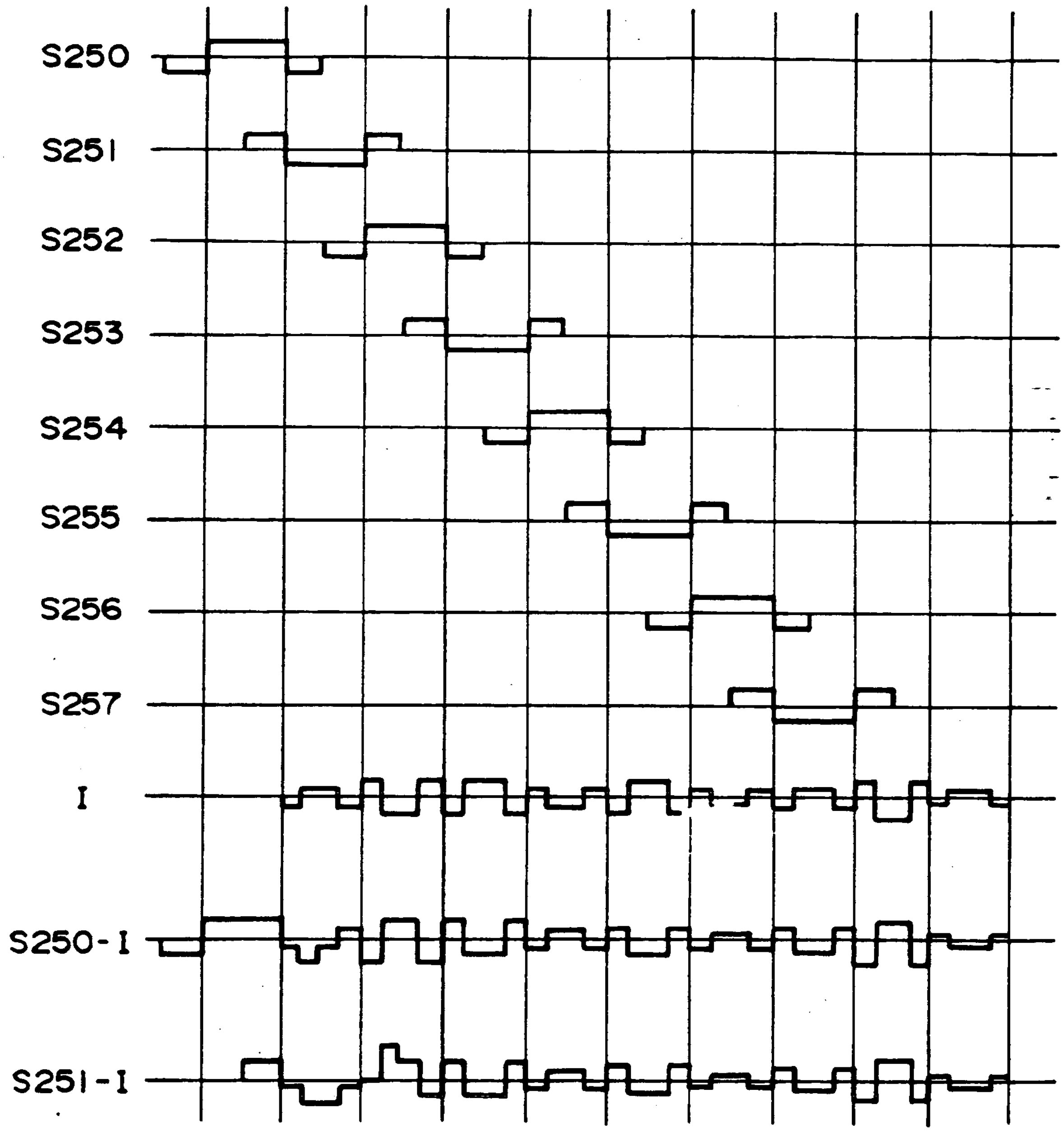



FIG. 13

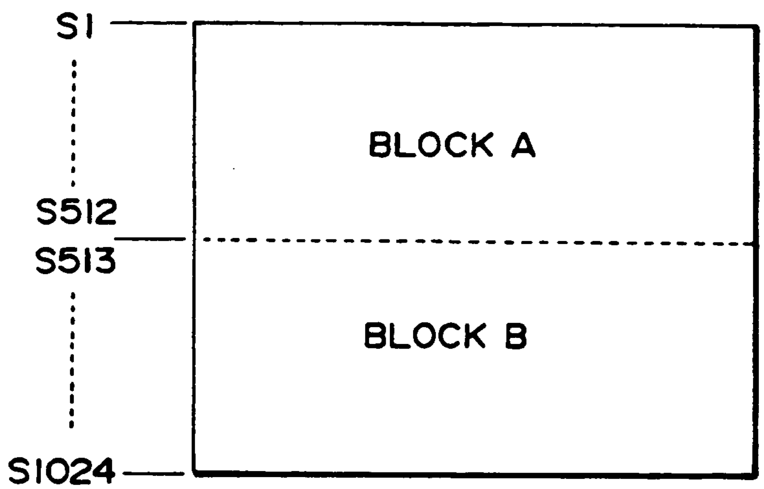



FIG. 15

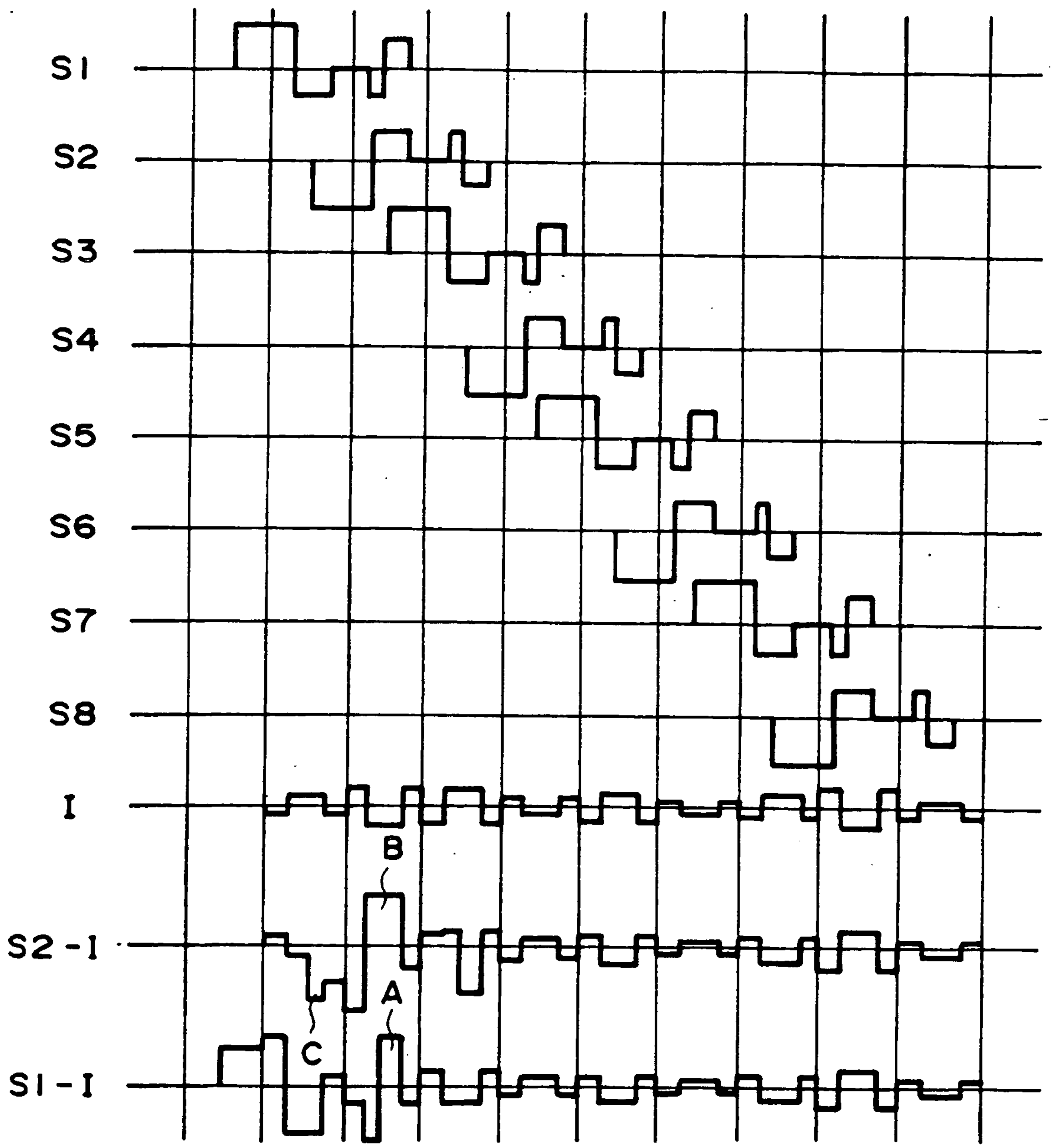



FIG. 17